

Drainage of Fields



The History of Our Drainage Enterprises

Hugh H. Wooten and Lewis A. Jones

American farmers since the early days of settlement have drained land.

In 1763 the Dismal Swamp area of Virginia and North Carolina was surveyed by George Washington and others with a view to land reclamation and inland water transportation. The Dismal Swamp Canal Company was chartered in 1787 by the two States. The canal was opened 7 years later. It is still a means of transportation and helps to prevent floods.

Early drainage works also were constructed in Delaware, Maryland, New Jersey, Massachusetts, South Carolina, and Georgia. Drainage work of concern to the public was carried out under the authority of colonial and State laws. Among the earliest laws are those of Maryland in 1790 and Delaware in 1816. The North Central States likewise became interested in land drainage shortly after settlement. Michigan and Ohio had drainage laws in 1847.

The early work which started in colonial days, consisted primarily of constructing small open ditches to drain wet spots in fields and of cleaning out small natural streams. Little engineering work was involved. In 1835 John Johnson of Seneca County, N. Y.,

brought over from Scotland patterns from which clay tile was molded by hand and laid on his farm. That was the beginning of modern tile drainage in the United States.

Settlement of the Ohio and Mississippi Valleys was just starting. Much of this land, though very fertile, could not be cultivated until it was drained, and malaria was prevalent in large areas. Here the use of tile spread rapidly; 1,140 tile factories, mainly in Illinois, Indiana, and Ohio, were in operation by 1880. More than 30,000 miles of tile were laid in Indiana by 1882.

Farmers learned that the success of many tile systems depended on large outlet ditches. The construction of such ditches increased rapidly as the North Central States were settled. The Ohio Society of Engineers and Surveyors reported in 1884 that in Ohio 20,000 miles of public ditches had been constructed, benefiting 11 million acres of land and improving the health of the citizens.

Drainage has added an estimated 25 million to 30 million acres to the tillable area in the North Central States and has increased production on about 37 million acres more.

Typical of the additions to our tillable land are large tracts in northwestern Ohio, northern Indiana, north central Illinois, north central Iowa, and southeastern Missouri. What the tracts were once like is described in the report on Long's expedition to the source of the Minnesota River in 1823,

written by W. H. Keating, of the University of Pennsylvania, who accompanied the expedition. The Long Expedition, undertaken by order of J. C. Calhoun, Secretary of War, sought information about the conditions in the country, then undeveloped, west of Pennsylvania.

Professor Keating described the land east of Fort Wayne, Ind., thus: "Near to this house we passed the State line which divides Ohio from Indiana. . . . The distance from this to Fort Wayne is 24 miles, without a settlement; the country is so wet that we scarcely saw an acre of land upon which settlement could be made. We travelled for a couple of miles with our horses wading through water, sometimes to the girth. Having found a small patch of esculent grass (which from its color is known here as bluegrass) we attempted to stop and pasture our horses, but this we found impossible on account of the immense swarms of mosquitoes and horse flies, which tormented both horses and riders in a manner that excluded all possibility of rest."

He also described the land south and west of Chicago:

"From Chicago to a place where we forded the Des Plaines River the country presents a low, flat, and swampy prairie, very thickly covered with high grass, aquatic plants, and among others the wild rice. The latter occurs principally in places which are under water; its blades floating on the surface of the fluid like those of the young domestic plant. The whole of this tract is overflowed during the spring, and canoes pass in every direction across the prairie."

Drainage changed those conditions. Today, the traveler who notes the well-cared-for productive fields, the substantial farm buildings, the good roads, and splendid school buildings, may not think that drainage made possible many of the developments—that without drainage the localities would be much the same as Keating described them in 1823. In both areas there are now more miles of public outlet ditches

and drains than there are miles of public highways.

THE SWAMP LAND ACTS of 1849 and 1850 were the first important Federal legislation relating to land drainage. They were the result of more than 20 years of discussion in the Congress of appropriate procedures for initiating reclamation of the wet lands of the public domain. For more than 75 years they were almost the only statement of Federal drainage policy. Under the acts, vast acreages of swamp and overflowed lands were transferred to the States on condition that funds from their sale be used to build the drains and levees necessary to reclaim them.

Under the Swamp Land Acts of 1849, 1850, and 1860, approximately 64 million acres of swamp and overflow land in 15 States were conveyed to the respective States to facilitate reclamation of the land for agricultural use. No important reservations were attached to this transfer, and the States were free to dispose of the land as they saw fit. In that way the Federal Government relinquished control of most of the potential drainage work in the public domain.

It has become common practice to dismiss as failures the drainage and flood-control projects started under the Swamp Land Acts. It is true that for the most part the States did not immediately develop the land as anticipated. But that is not the whole story.

Over the lower Mississippi Valley States, where administration and use of swampland funds was a major political, economic, and social issue for more than 30 years, reclamation carried out under the Swamp Land Acts permanently affected the agricultural economy. Experiences in flood control and drainage engineering, gained in trying to meet the provisions of the grants, formed the basis for the elaborate drainage projects later undertaken by local districts and by the States and the Federal Government for control of floods in the lower Mississippi Valley. Likewise most of the legal and admin-

istrative concepts and machinery set up under the Swamp Lands Acts became a permanent part of flood-control and drainage practices.

According to the wording of the Swamp Land Acts, the reclamation included both flood control and drainage. But State and Federal legislators alike underrated the complexity and cost of flood control and drainage in the lower Mississippi Valley. Receipts from the sale of swamplands were a pittance compared to the amount required to control floods and improve drainage. Historically the Swamp Land Acts are significant chiefly because of the vast transfer of lands made under them—first from the Federal Government to the States, soon thereafter by State governments to the counties and the levee boards, and later to private citizens and corporations.

Disastrous floods occurred frequently from 1850 through 1900. Loss of life and property led to increased expenditures for flood-control work each year. Flood-control improvements in time grew to an impressive size. With their increasing enlargement, waves of optimism found expression in the development of new land. By 1900 or so, it appeared that public reclamation work should include land drainage besides levee building. Soon the landscape of much of the Delta region was altered through drainage activities initiated and financed through creation of local drainage districts under State laws.

DRAINAGE IS A LAND IMPROVEMENT and cultural practice on about 2 million farms. The agricultural census of 1950 reported nearly 103 million acres of land in organized district and county drainage enterprises in 40 States. More than 900 million dollars, or an average of about 9 dollars an acre, has been expended on public drainage improvements on the 103 million acres, which is larger than the combined areas of Ohio, Indiana, and Illinois. More than 155,000 miles of outlet ditches, 56,000 miles of main outlet tile drains, 7,800 miles of levees, and pumping plants of

more than 110,000 horsepower have been constructed. The enterprises range from fewer than 100 acres to more than 1 million acres; they average about 7,300 acres.

Of the 103 million acres in drainage enterprises, some 15 million acres are still too wet for cultivation; crop losses are frequent on an additional 10 million acres because of poor drainage.

Those unsatisfactory conditions are due primarily to lack of sound engineering in designing the improvements and to poor maintenance.

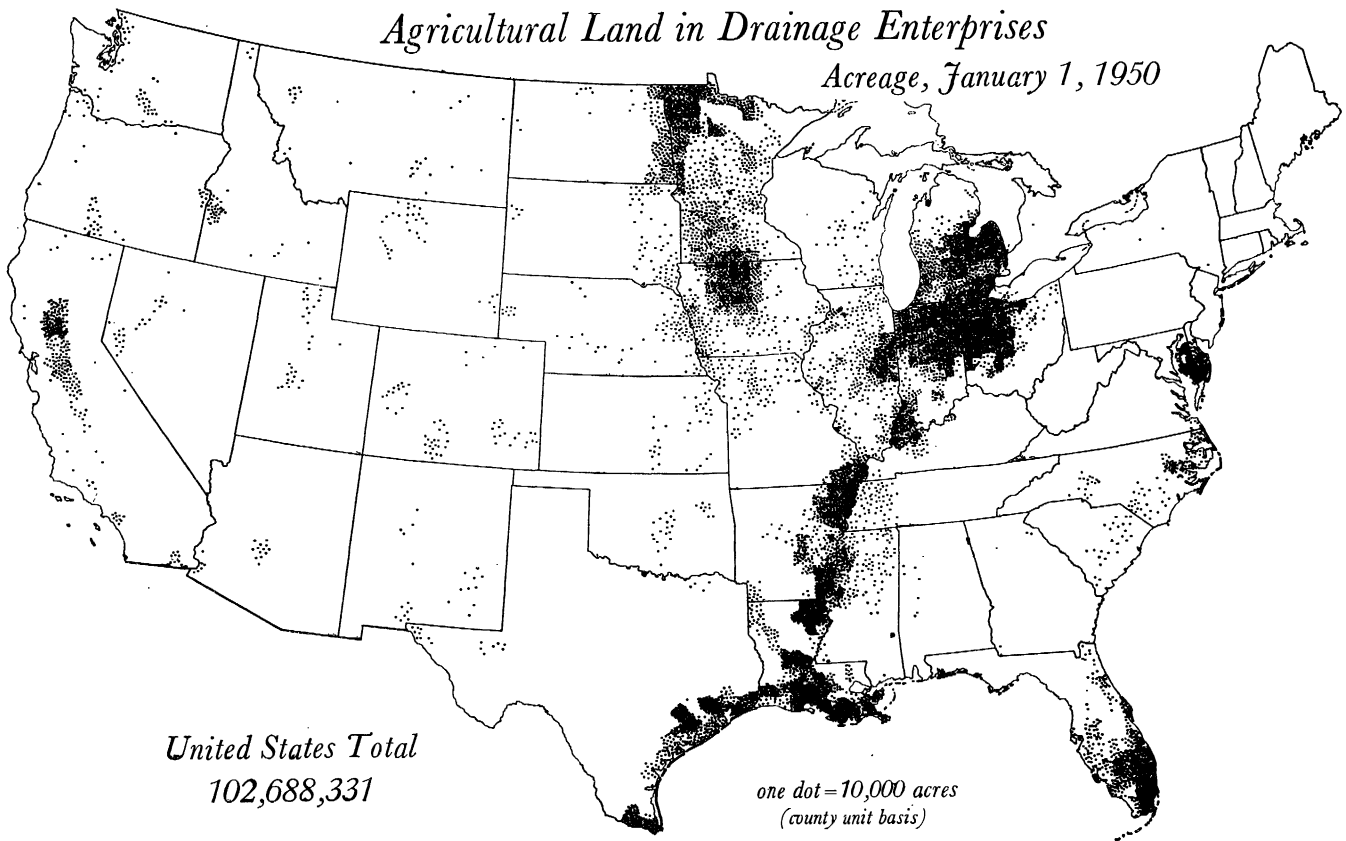
Besides the land in organized public drainage enterprises, we estimate that more than 50 million acres of wet farmland have been drained by individual, private projects. We have no reliable record as to the amount of money spent or the number of miles of field ditches and tile drains that individual farmers have installed on field drainage, but the expenditure for such work is estimated to be many times the amount spent on outlet drainage.

In constructing public drainage improvements only main outlets as a rule are provided. Before their land can be farmed to the best advantage, farmers usually must install necessary farm drains, clear and level the land where necessary, and otherwise prepare it for cultivation.

The map and tables with this article show where the drained lands are located and the rate at which drainage is done. Land in organized drainage enterprises is largely in the Corn Belt, Lake States, and the Mississippi Delta. Between 1920, when the first census of drainage was taken, and 1950, the greatest increase of land in drainage enterprises occurred in the Delta and Corn Belt States. The Southeastern region had a high proportional increase. The relatively little drainage work done in the Western States has been mostly in connection with irrigation.

Between 1940 and 1950, the land in drainage enterprises increased by nearly 16 million acres. Half of the increase was in the Mississippi Delta. Another

Agricultural Land in Drainage Enterprises
Acreage, January 1, 1950



United States Total
102,688,331

one dot = 10,000 acres
(county unit basis)

*Acreage of Land in Organized Drainage Enterprises Regions
and by Specified Years, 1920-1950*¹

<i>Region</i> ²	<i>1920</i>	<i>1930</i>	<i>1940</i>	<i>1950</i>	<i>Change 1940-1950</i>
	<i>1,000 acres</i>	<i>1,000 acres</i>	<i>1,000 acres</i>	<i>1,000 acres</i>	<i>1,000 acres</i>
Northern:					
Northeastern.....	0	0	578	744	166
Lake States.....	19,757	21,548	20,730	21,979	1,249
Corn Belt.....	28,924	32,700	32,194	35,194	3,000
Northern Plains.....	2,164	2,929	3,227	3,457	230
Total.....	50,845	57,177	56,729	61,374	4,645
Southern:					
Appalachian.....	1,265	1,873	1,908	2,750	842
Southeastern.....	1,843	6,247	6,016	6,506	490
Mississippi Delta.....	7,347	11,275	11,703	19,886	8,183
Southern Plains.....	2,178	3,054	4,416	6,096	1,680
Total.....	12,633	22,449	24,043	35,238	11,195
Western:					
Mountain.....	810	1,970	2,773	2,671	³ - 102
Pacific.....	1,207	2,812	3,422	3,405	³ - 17
Total.....	2,017	4,782	6,195	6,076	³ - 119
United States.....	65,495	84,408	86,967	102,688	15,721

¹ Bureau of the Census: Census of Agriculture, 1950, Drainage of Agricultural Lands, vol. 4, 1950.
² Including irrigation enterprises that have their own drainage.
³ Decrease indicated by minus sign.

*Drainage Development and Use of Land in Drainage Enterprises in the
United States to 1950*¹

<i>Year</i>	<i>Land in all enterprises</i>	<i>Drained</i>	<i>Improved</i>	<i>In planted crops</i>
	<i>1,000 acres</i>	<i>1,000 acres</i>	<i>1,000 acres</i>	<i>1,000 acres</i>
Before 1870.....	171	150	133	97
1870-79.....	428	404	373	288
1880-89.....	2,429	2,267	2,173	1,865
1890-99.....	3,743	3,500	3,256	2,482
1900-04.....	5,769	5,414	5,134	3,814
1905-09.....	12,192	11,081	10,340	7,652
1910-14.....	19,573	14,138	12,281	9,006
1915-19.....	18,012	16,262	14,067	10,268
1920-24.....	11,272	10,028	8,848	6,480
1925-29.....	7,411	6,824	6,188	4,511
1930-34.....	2,093	1,974	1,788	1,326
1935-39.....	3,874	2,962	2,808	1,824
1940-49.....	15,721	14,749
Total to 1950.....	102,688	82,138

¹ Bureau of the Census: Drainage of Agricultural Lands [1940], 1942; Drainage of Agricultural Lands, vol. 4, 1952.

4 million acres of the increase occurred in the Lake States and Corn Belt.

Texas also had a large increase. The three regions, with Texas and Florida, accounted for three-fourths of the land in drainage enterprises in 1950.

Farm and district drainage sometimes has been aided by the building of major channels and outlets by the Corps of Engineers, particularly in the Mississippi Valley. These new or improved outlets have encouraged the organization or reactivation of many drainage districts in order to improve local drainage ditches and reap the benefits of better main outlet drainage.

Most public drainage projects, however, were undertaken by local drainage districts and counties, and the investment was made chiefly by private citizens through local taxes or special assessments on the property that was benefited. But individual farmers and small groups have had limited financial and technical aid for farm drainage from the agricultural and soil conservation programs when such work contributed to the overall conservation plan for a farm or local area.

TWO MAJOR FORMS of organization are provided under the drainage laws.

In one, which may be called the "county form," management of the affairs of the enterprise is in the hands of county officials, who may or may not be personally interested in the enterprise. In the other, which may be called the "district or corporate form," management is in the hands of a board elected by the landowners of the enterprise. Both forms operate effectively when they are well administered. Under both forms, drainage work can be financed by sale of bonds, which are to be refunded over a period of years. The bonds are a first lien on the benefited land in the district; they rank immediately after State and county taxes and ahead of land mortgages.

State laws generally provide the landowner with a means of organizing to obtain drainage improvements, a method of apportioning the cost of the

work, the right to levy and collect taxes from all who receive benefits, the right of condemnation against private property for public use, and a method of financing by the sale of bonds to be refunded over a period of years.

DRAINAGE LAWS in most States have been developed gradually from the time of settlement as larger and more costly improvements have been planned. The many amendments, revisions, and supplemental acts passed by the legislatures sometimes have resulted in inconsistent or even contradictory provisions, so that the meaning must be determined by the courts.

The courts have written decisions on many phases of drainage. They have pretty well established the requirements for such legislation. In attempts to meet the decisions, the States usually have amended and reamended their drainage laws without giving consideration to the law as a whole. In some States the laws make no provision for maintaining drainage works after they have been constructed. In other States methods of assessing benefits are unsatisfactory. In most States the laws establish the procedures and the safeguards necessary in large drainage enterprises that require bond issues, but they fail to provide simple and inexpensive procedures for organizing and operating small enterprises where the work can be paid for in cash. A competent committee organized in each State where drainage is important could profitably study existing drainage legislation and court decisions and prepare recommendations for improvement of existing laws.

ORGANIZATION OF DRAINAGE districts requiring bond issues was confined before 1910 primarily to the North Central States. A few districts were in the alluvial area of the lower Mississippi Valley. With the fertile prairie soils and generally smooth lands of the North Central States, engineering problems were simple, cost of drainage was low, and expenses of putting the

land into cultivation were small. Much of this early work proved profitable and made possible development of some of the most fertile and profitable agricultural areas in the country.

Drainage work was continued, with only few exceptions, on a conservative basis until about 1915, when the period of high prices resulting from the First World War led to the speculative development by drainage of large areas of cutover forest, swamp, and marsh in nearly all of the Mississippi Valley and the Southern States. Many of these projects encountered financial difficulties for one reason or another from 1925 to 1940 and required adjustment and refinancing of debt.

In many such districts the promoters failed to take into consideration such items as soil fertility, cost of developing farm units after drainage was completed, cost of maintaining drainage improvements, and markets for the farm products to be grown. Plans for drainage were incomplete in some districts or improvements were designed with insufficient capacity. Large areas remained poorly drained and could not be made to produce profitable crops without extensive additional work. Difficulties in most cases were due to poor planning and piecemeal methods of drainage. Some districts did not employ competent drainage engineers. Many of the projects were unsound from the beginning because the soils were unsuitable for tillage or not sufficiently fertile to warrant development or because lack of control or erosion from surrounding hill lands made it impracticable to maintain the drainage improvements.

TO AVOID SUCH DIFFICULTIES in the future, enough investigations should be made by those interested to determine the desirability of drainage enterprises from the soil and land-use viewpoints, to develop sound engineering plans, and to finance the work on a reimbursable basis.

The need for this type of work has been recognized by Louisiana, which

in 1940 inaugurated a program of rehabilitating existing drainage enterprises and helping to develop new enterprises. Other States have considered similar programs.

THE FEDERAL GOVERNMENT carried on only a slight amount of direct land drainage before the organization of the emergency public works program in the 1930's. Its functions were mostly advisory or indirect. In more recent years, with the organization of new Federal financing agencies and the corollary expansion of construction work by old agencies, the functions broadened notably.

The nature of these activities generally is defined by legislation only so far as congressional authorization of annual agency appropriations implies approval of the current program. In making appropriations for the work of the Department of Agriculture, Bureau of Reclamation, and Corps of Engineers, the Congress has authorized certain types of research, financial aid, and construction relating to drainage, particularly where conservation, reclamation, and flood control were involved. Federal assistance with respect to drainage activity also has been provided specifically by the Congress in other ways.

THE CONGRESS has granted rights-of-way and easements to canal and ditch companies for constructing improvements through the public domain. It has authorized a decennial census of drainage enterprises. It also authorized the Federal Reserve Bank to buy and sell drainage district securities, authorized bankruptcy courts to receive petitions from drainage districts for readjustments of debts, and empowered the former Reconstruction Finance Corporation to finance refunding operations for existing drainage projects. Thus Federal concern from 1925 to 1940 was chiefly with rehabilitation of enterprises suffering economic distress. A considerable part of the distress was due to ill-advised and speculative de-

velopment of drainage projects by non-Federal interests in the past.

In the Flood Control Act of December 22, 1944, the Congress authorized work on channels and major drainage improvements as a part of the national flood-control program. Under the act, main channels and outlet ditches that serve many existing enterprises can be improved if the work is of widespread public benefit. Here the Corps of Engineers were for the first time instructed to engage in drainage work not directly related to levee building and other flood-control projects.

A new stage in Federal policy relating to drainage was reached with the enactment of the Watershed Protection and Flood Prevention Act of August 4, 1954. That act authorized the Department of Agriculture to cooperate with States and local agencies in planning and carrying out works of improvement for soil conservation and other purposes, including land drainage.

IN THE EARLY DEVELOPMENT of drainage work, outlet ditches were constructed by hand or with teams and scrapers. With such methods, the ditch that could be economically constructed could not be more than 5 feet deep; the bottom width seldom exceeded 4 feet. As the size of projects increased, such ditches did not provide the drainage desired.

An economical means of constructing large open ditches was sought. In 1883 the first dipper dredges were developed. For many years such machines were widely used.

The dipper dredge was followed in 1906 by the dragline excavator, which has been in general use since. It is a flexible machine. It is built in many sizes, and can dig ditches 3 to 150 feet in bottom width and 3 to 20 feet deep efficiently and economically. The newest models of draglines generally are diesel-powered and mounted on caterpillar tracks.

Until 1880 or so all tile drains were constructed by hand. As size of tiles and depth of drains increased, a ma-

chine that would dig trenches was needed. In 1883 the plumb ditching machine, powered by a steam engine, was placed on the market. Not much later several other steam-operated machines were built. Our modern, efficient tile-trenching machines were developed from them. The smaller machines can dig trenches up to 4.5 feet deep and about 1 foot wide. The larger machines dig trenches up to 6 feet deep and 1.5 feet wide. Operated efficiently under average conditions, a good trenching machine can excavate 2,000 to 3,000 feet of trench a day.

Use of drainage wheels, operated by animal power, to drain lowlands without gravity outlets was early practice among the plantations of the gulf coast, especially on sugar plantations. About 1850 pumps began to be used. As the projects became larger, low-lift centrifugal pumps gradually replaced other types. The wood screw pump was developed in 1915. It is widely used on the larger pumping projects.

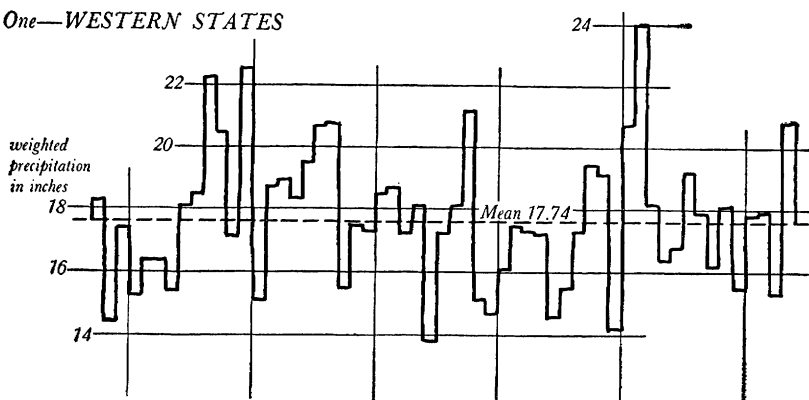
The periods of the most land drainage, as measured by the acreage added to drainage enterprises, coincide generally with periods of average and above-normal precipitation. Precipitation was high in the Mississippi Valley and Eastern States from 1900 to 1925, for example, and much agricultural land was drained then. From 1925 to 1940, when precipitation was less, drainage was less active; the increased rainfall of the 1940's again gave drainage a fillip.

An accompanying chart shows the weighted average precipitation in departures from normal for four regions of the United States from 1892 to 1953. An examination of the graphs discloses some interesting trends in comparison with a table that shows drainage development and use of land in drainage enterprises by periods.

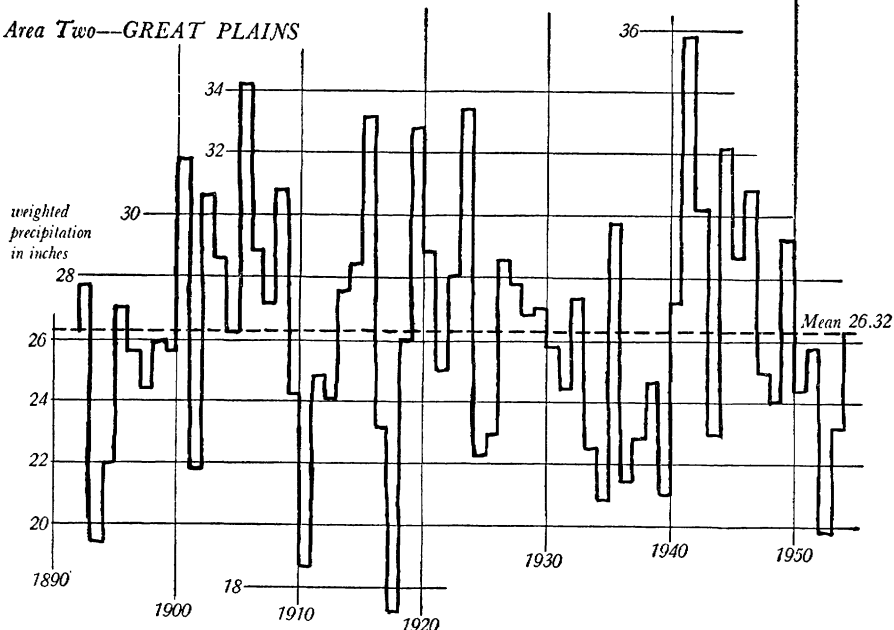
Periods of above-average activity in land drainage generally have coincided with or followed periods of heavy demand and rising prices for farm products. For example, drainage construction was heavy from 1909 to 1929,

Precipitation Characteristics and Trends

Area One—WESTERN STATES



Area Two—GREAT PLAINS

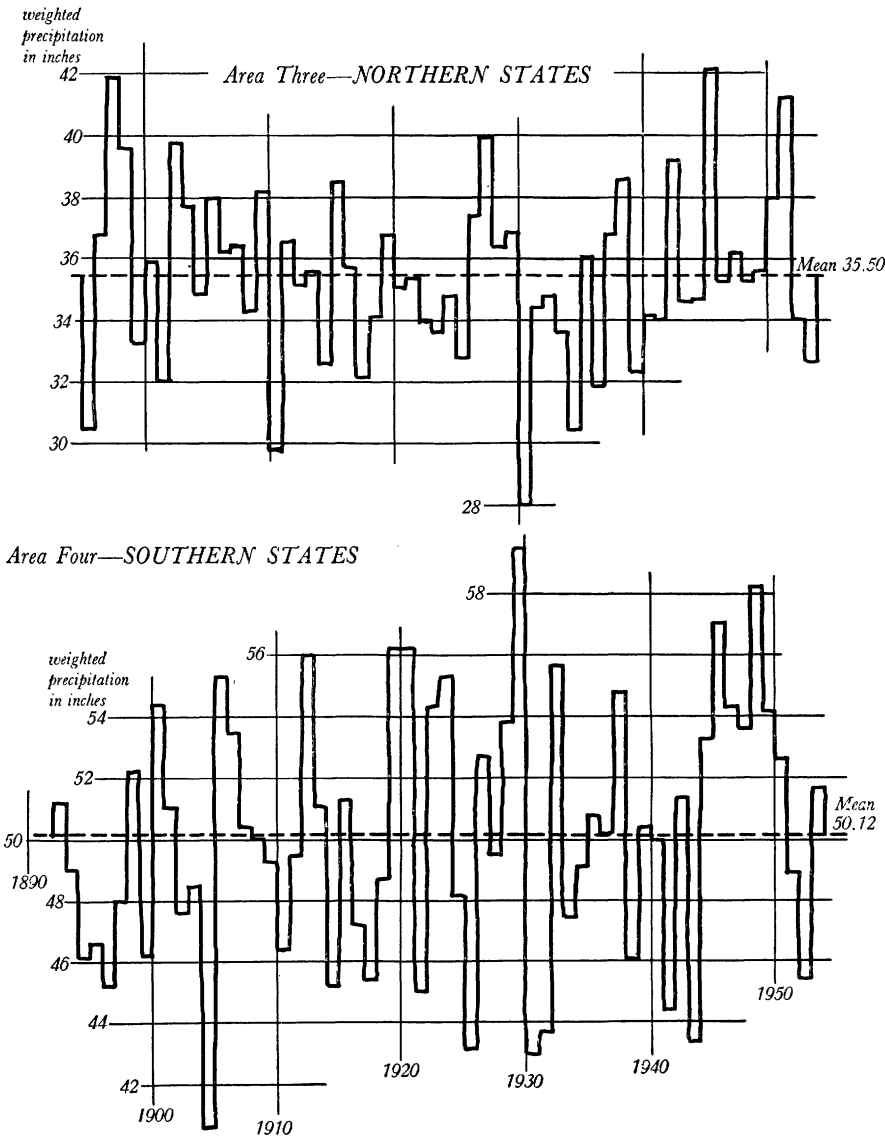


Precipitation characteristics and trends. The comparatively longtime trends in precipitation have a significant bearing on land development. Year-by-year weighted average precipitation, 1892 to 1953, in percentages of departures from the normal, are given for four areas. Area 1 comprises 11 Western States, or Pacific and Mountain States; Area 2, the 6 Great Plains States, North Dakota to Texas; Area 3, the Northern States, including the Corn Belt, Lake, and Northeastern States; and Area 4, the Southern States, including the Mississippi Delta States and the Southeastern and Appalachian States.

when demand for farm production was increasing and when prices and income were considerably above those of the preceding decade. Costs of farming as

well as costs of construction, including wages, were also higher during periods of high production and heavy drainage activity. But during periods of low

Precipitation Characteristics and Trends



farm prices, some drainage construction and other types of farmland improvement were made in order to increase crop acreages and maintain farm incomes. Farm production has varied much less than prices between periods of heavy and low demand.

The Engineering News Record Construction Cost Index shows that from 1910 to 1929 construction costs as a whole were less than 40 percent of those from 1949 to 1953. Prices paid by farmers for production materials and labor from 1910 to 1929 were

about 50 percent of what they were from 1949 to 1953.

THE MILLIONS OF ACRES once too wet to be cultivated and since reclaimed now rank among the most valuable agricultural areas of the country. Additional millions of acres, where crop losses were frequently due to inadequate drainage, now produce well.

Twenty-one counties in northwestern Ohio and northeastern Indiana in the area in which there was originally much low land, impossible to cultivate, now comprise one of the most productive areas in the country. According to the 1950 census, this area produced for sale more than 225 million dollars worth of agricultural products in 1949.

The north central part of Iowa has extensive areas of flat land, which comprises about 90 percent of 11 of Iowa's richest agricultural counties. At the time of settlement much of this land was in shallow sloughs, which were wet during so many seasons that they could not be cultivated. The rest of the area could be cultivated, but crop yields were generally low because of lack of drainage outlets. Drainage work was started soon after settlement. Today this extensive area is included in drainage enterprises and has drainage outlets. In 1949 the value of agricultural products raised and sold from the area totaled about 200 million dollars. At least 50 percent of that production would not have been possible without drainage.

In southeastern Missouri one drainage district of 400,000 acres, with other smaller districts, covers much of the agricultural area of five counties. In 1909, before drainage, the only land under cultivation was small patches along streams. Less than 5 percent was cultivated. The rest was swampland. Drainage work was started about 1912. Now 95 percent of the area is under cultivation and includes some of the most valuable land in Missouri. The value of farm products sold from the area in 1949 was more than 75 million dollars.

Large areas in western Minnesota, central Illinois, northeastern Arkansas, the gulf plains of Texas, and the delta areas of Mississippi and Louisiana were originally swamp and overflow areas. Drainage permitted cultivation.

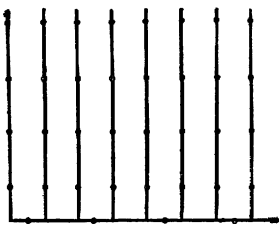
It is estimated that drainage has added 50 million to 60 million acres of fertile swampland to the cultivable area of the United States and that production has been increased on an additional 75 million to 100 million acres.

Some mistakes have been made. Some land of little value to agriculture has been drained. It has also been damaged for wildlife. In other areas the plan of drainage proved to be unsatisfactory and too costly. In some places no provisions were made to control sediment or to maintain ditches and other works, and within a few years the drainage improvements were destroyed.

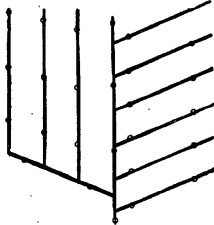
EVERY STATE has some land that can be improved through drainage, but the largest areas of wet land are in the eastern half of the country. A large total acreage that could be drained lies in the Southeast, in creek and river bottoms and along the Atlantic coast. The Mississippi Valley has additional thousands of alluvial acres, which can be improved for farming as needed. In the Lake States and the Corn Belt there is still much potentially good land that could be put in better shape for the plow by drainage.

An estimated 20 million acres of fertile undeveloped land needs to be drained if farmland is to be developed from it. Roughly 7 million acres of this drainable land is found in the fertile bottomlands of the Mississippi River, in Arkansas, Louisiana, and Mississippi. Another 7 million to 8 million acres are scattered in the Coastal Plains and other parts of the Southeast. But if this acreage were shown on the map, the dark, dotted space would be increased about a fifth; in the Southeast it probably would be more than doubled. Not all wet land is suitable for drainage. At least 75 million

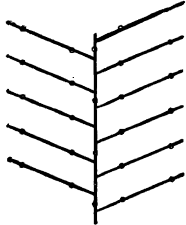
Types of Tile Drainage Systems



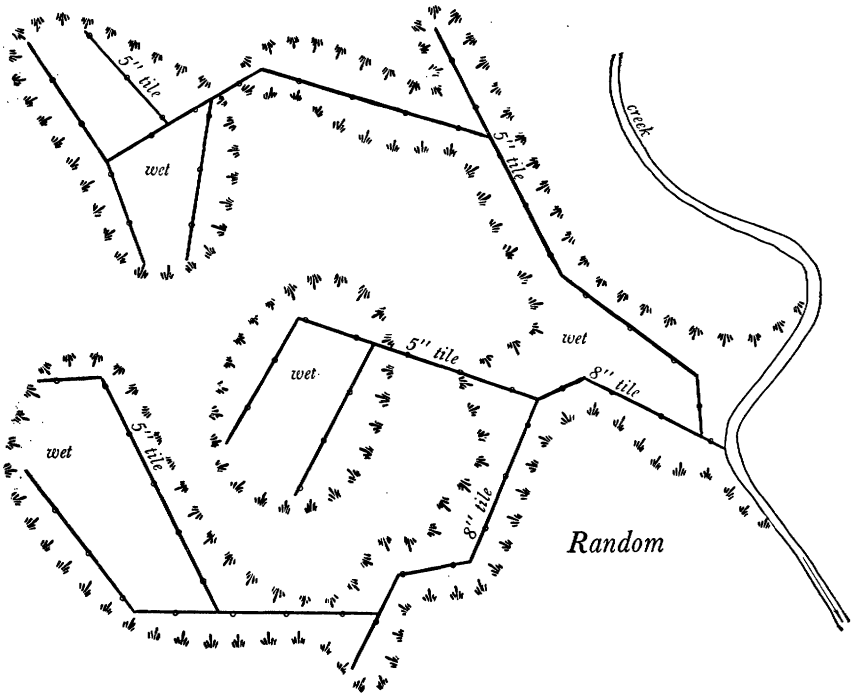
Parallel



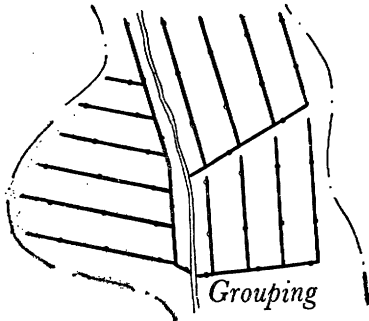
Gridiron



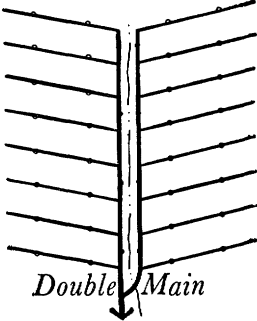
Herringbone



Random



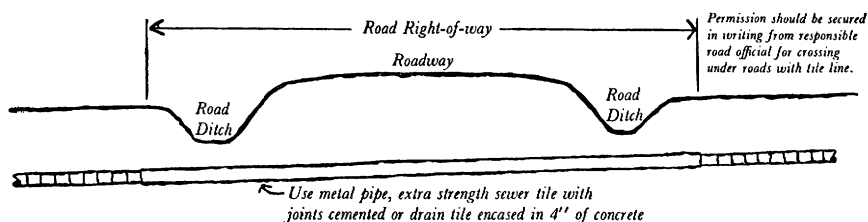
Grouping



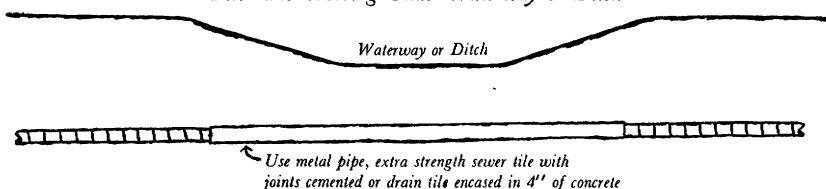
Double Main

Tile Line Crossings and Handling Shallow Tile Outlets

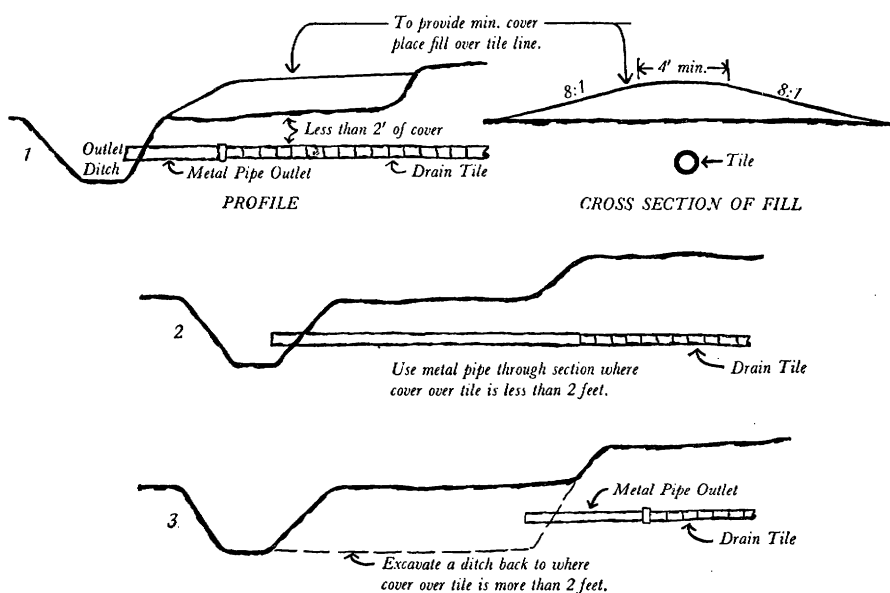
Tile Line Crossing Under Road



Tile Line Crossing Under Waterway or Ditch



Methods for Handling Shallow Depths at Tile Outlet



acres of wet land in the United States are unsuited for agriculture under present conditions, but they can be used for wildlife, forests, and recreation.

HUGH H. WOOTEN has been in charge of land utilization research in the Land and Water Section (formerly the Land Economics Division of the Bureau of Agricultural Economics), Agricultural Research Service, since 1942. Trained at the North Carolina State College of Agriculture and Engineering and the University of North Carolina, he has devoted 25 years to work in agricultural economics. He has lived and worked in 12 States of the South, West, and Midwest and has contributed to several bulletins and other publications.

LEWIS A. JONES has been actively engaged in agricultural drainage work for more than 40 years, first as civil engineer in charge of various drainage projects and investigations and for the last several years in charge of drainage research in the Soil Conservation Service. He is a native of Minnesota and has worked in all the Midwestern and Southern States and in other areas where land drainage is a problem.

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Technical Problems and Principles of Drainage

T. W. Edminster and J. van Schilfgaarde

Excess water becomes a problem when it interferes with tillage, land preparation, the development of plants, and harvest operations.

Much of the excess water is removed naturally by surface runoff, deep seepage, evaporation, and transpiration, but those processes often are too slow to prevent damage to the crop, and farmers must resort to drainage to remove the water faster.

We define agricultural drainage as the removal by artificial means of excess water from the soil profile to enhance agricultural production—more specifically, the removal of excess gravitational water from the soil. The word excess implies that drainage water cannot be considered as water lost, for it never was available for plant growth. The word gravitational indicates that drainage water is not held in the soil by any forces except gravity.

Surface drainage systems are designed primarily to remove water that is on the surface and has not entered the soil profile. That is done by developing the slope of the land so that the excess water will flow by gravity to a system of shallow field ditches, which empty into larger mains and extend to a satisfactory point for disposing of the water.

The removal of water that has already entered the soil profile is considered subsurface drainage. Thus open-ditch drainage removes surface water but is classified as subsurface drainage because the ditches affect the movement of ground water to the same degree as mole or tile drains placed at the same depth.

Essentially any one drainage problem must be considered as a combination of surface and subsurface water removal. They are interdependent;